

# A Hard X-Ray Telescope for the Con-X SEP

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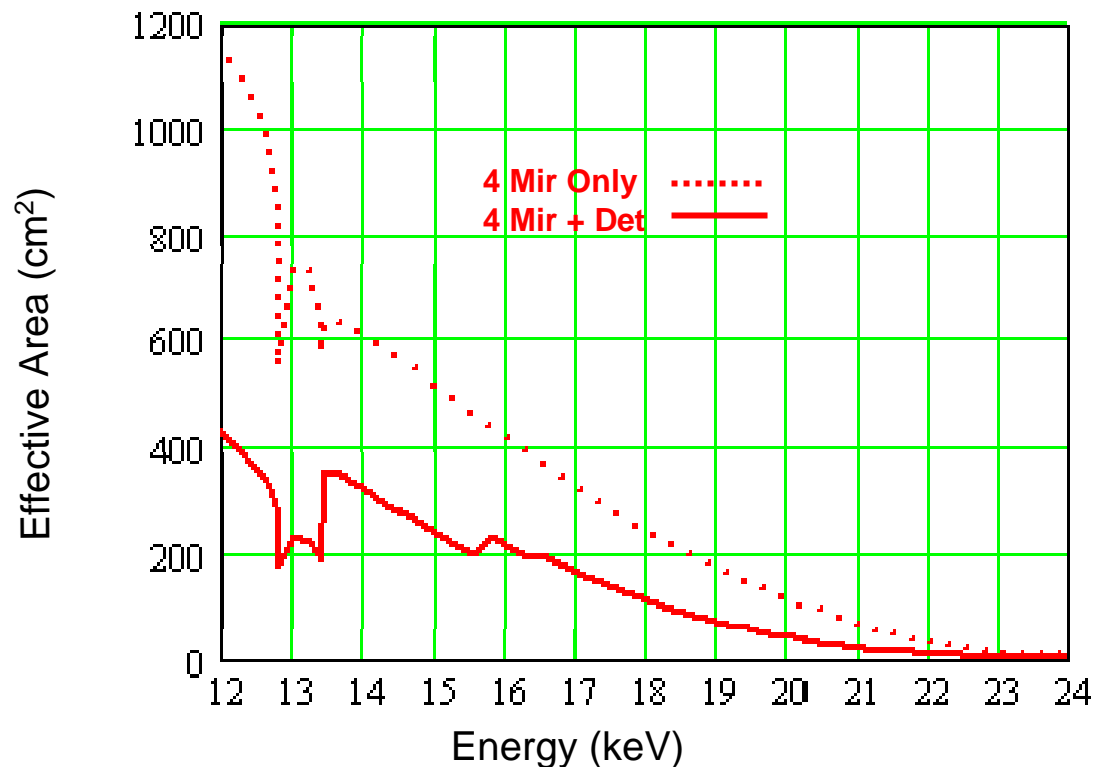


A Hard X-Ray Telescope for  
the Con-X SEP

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# Introduction

Effective area of the SXT (w/wo det.) is falling rapidly past 12 keV to ~ 0 at 22keV



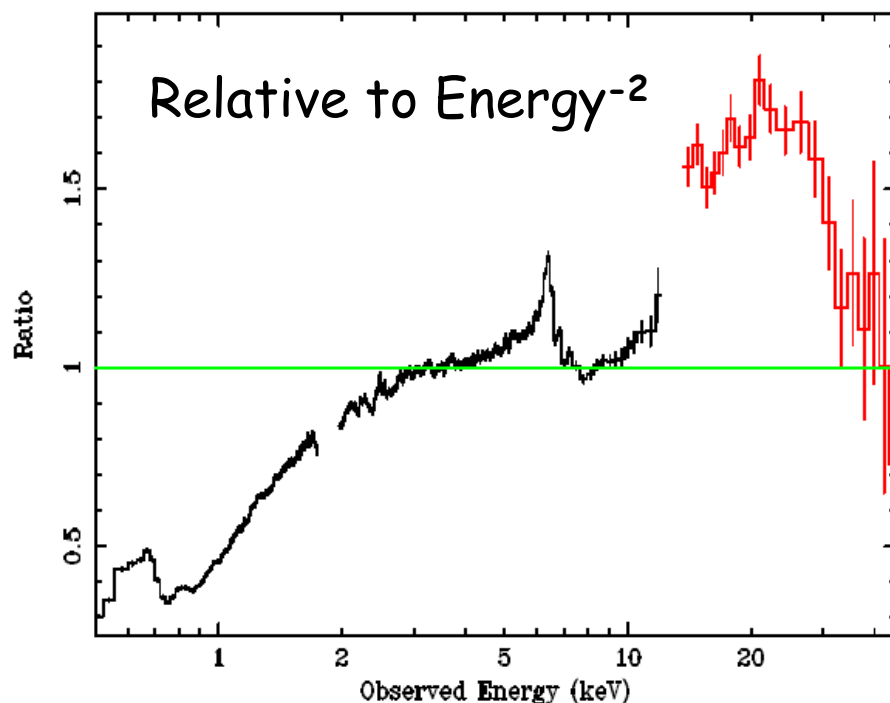
# The bandwidth of Con-X should be broader than the SXT's

- Con-X is an X-ray spectroscopy mission that is also a national observatory : it should be able to detect the existence of multiple spectral components
- The existence of a non-thermal component amidst a thermal component will usually be more easily detected at higher energy where the thermal component has fallen
- Con-X will study the non-thermal spectra of AGN jets and cyclotron-synchrotron radiation from highly magnetized neutron stars
- An HXT will have more sensitivity between 15 and 40 keV than any previous instrument such as OSSE, INTEGRAL & Swift. The effective bandwidth is much larger for objects with  $z > 1$ .
- The existence of a continuum that is not properly accounted for can affect our measurement of the profile of an Fe line that experiences a gravitational redshift from being in proximity to a black hole.

# Suzaku Spectrum of the Seyfert galaxy MCG-6-30-15

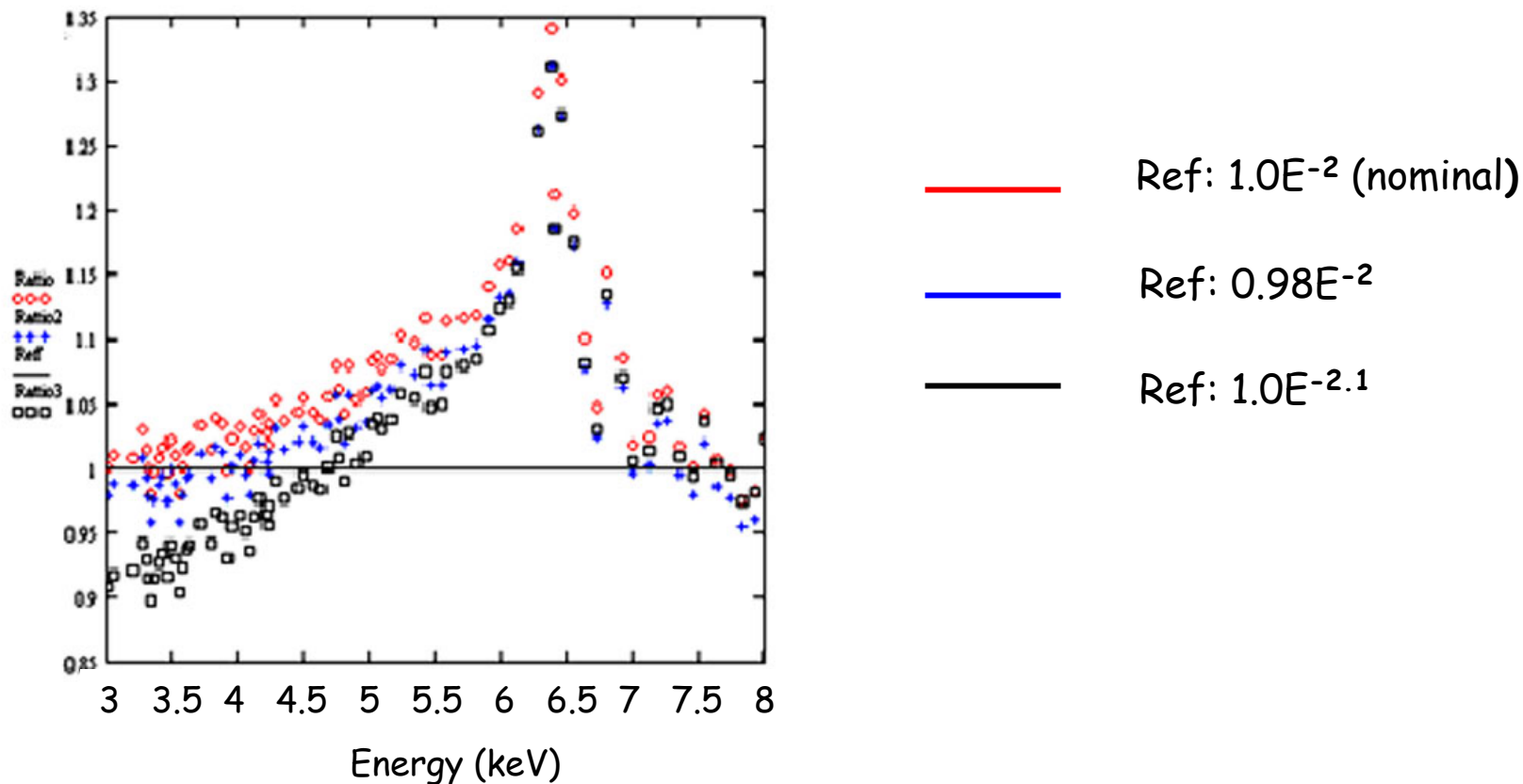
— X-ray imaging spectrometer  
(CCD)  
— Hard X-ray detector

Miniutti et al (20+ authors), 2006, *PASJ*  
(in press). Also astro-ph 0609521



Fe abundance is 3x solar.  
Perhaps the best candidate  
of a gravitational broadened  
Fe line.

## Sensitivity of Fe profile to variations in the continuum



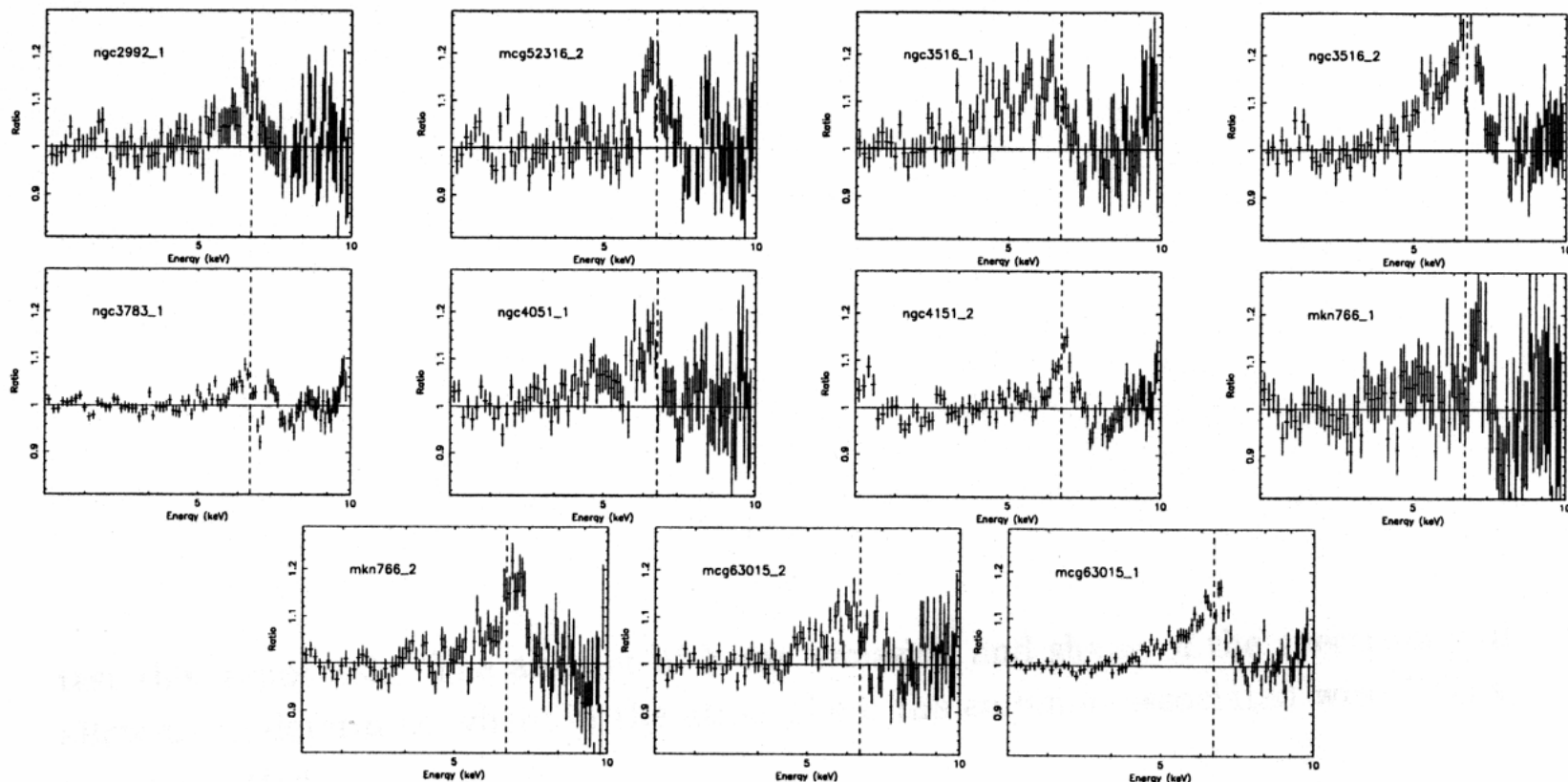
# XMM-Newton Survey of Broad Lines in AGNs

Nandra et al, 2006 *Astron. Nachr.* **327**, 1039

## Large variation in Fe line/Continuum ratio

1042

K. Nandra et al.: Broad lines in AGN



**Fig. 3** The relativistic line “dream team”: data/model ratios are shown in cases where the broad line emission is constrained to come from within  $R_{\text{br}} < 20R_g$ , and for which the alternative model narrow line blends plus warm absorber gives a worse fit by  $\Delta\chi^2 > 10$ . The reference continuum is a power law, with a warm absorber where necessary. Narrow line emission at 6.4 keV, with associated Compton reflection, is also included so the above ratio plots may underestimate any contribution at 6.4 keV from the accretion disk line.

# Variability in the Continuum of NGC 4151

Mon. Not. R. Astron. Soc. **345**, 423–428 (2003)

## Iron K-features in the hard X-ray *XMM–Newton* spectrum of NGC 4151

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### ABSTRACT

Recent *XMM–Newton* observations have measured the hard (2.5–12 keV) X-ray spectrum of the well-known Seyfert galaxy NGC 4151 with a signal-to-noise unprecedented for this source. We find that a spectral model, developed to fit previous *BeppoSAX* and *ASCA* observations of NGC 4151, provides an excellent description of the *XMM–Newton* European Photon Imaging Camera (EPIC) data. The results support the view that it is the level of the continuum that is the main driver of the complex spectral variability exhibited by NGC 4151.

# Several means of extending Con-X's bandwidth

1. Replace the iridium coatings of all or some SXT mirror shells with multilayers.
2. Reposition some SXT mirrors to smaller radii to reduce their graze angles, with or without changing Ir coatings to multilayers.
3. Add more mirror shells to the SXT with lower radii, with or without multilayers. That is, increase the size and mass of the SXT
4. Insert another telescope in the hole between the smallest radius SXT shell and the optic axis.
5. Place separate telescopes with their own detectors outside of the SXT mirrors.

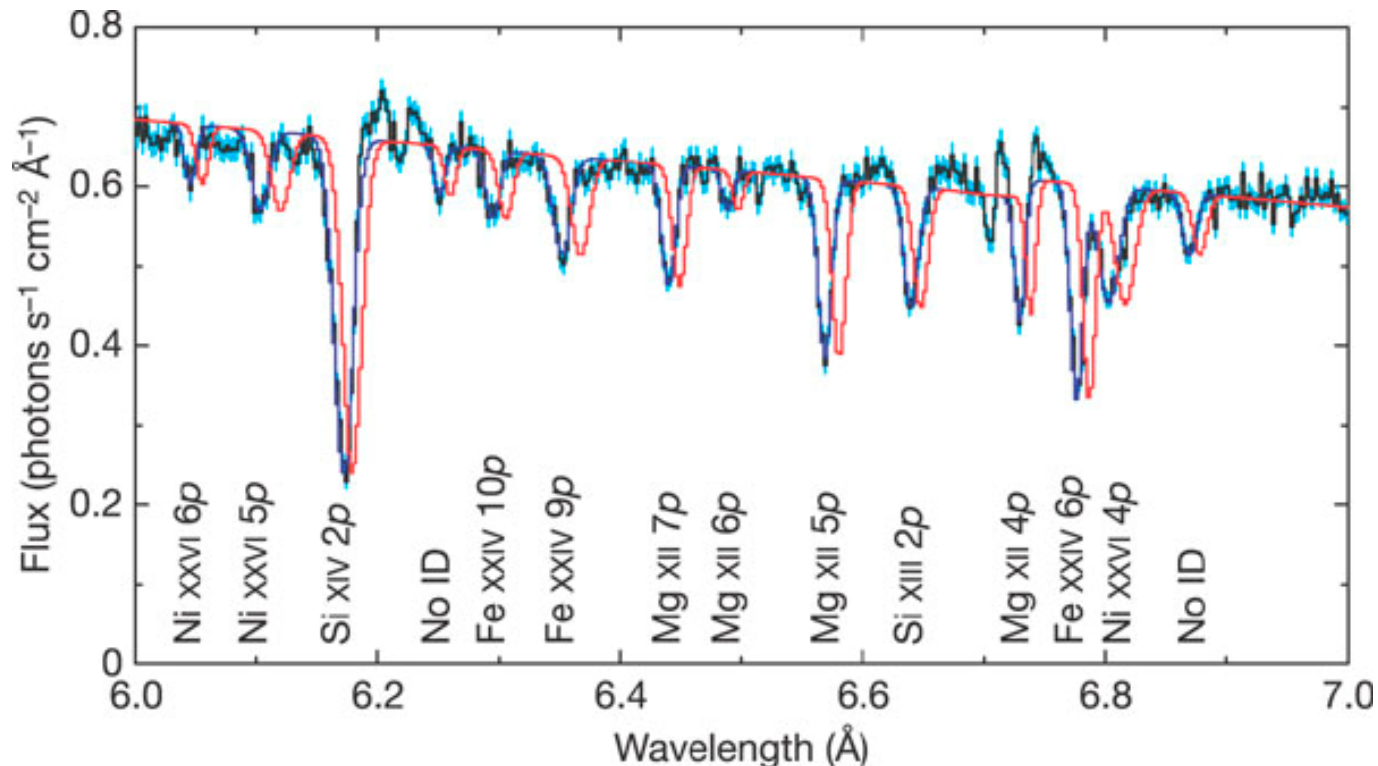
**Methods 1. - 4. use the same detectors as the SXT.**

# In Extending the Bandwidth of Con-X: Observe These Principles

- Do not increase the difficulty of constructing or calibrating the SXT
- Do nothing that would degrade the angular resolution of the SXT. Loss of angular resolution affects the quality of both spectrophotometric imaging and dispersive spectroscopy
- Always use the highest energy resolution detector (as seen in next two slides) to observe the broad Fe line profile

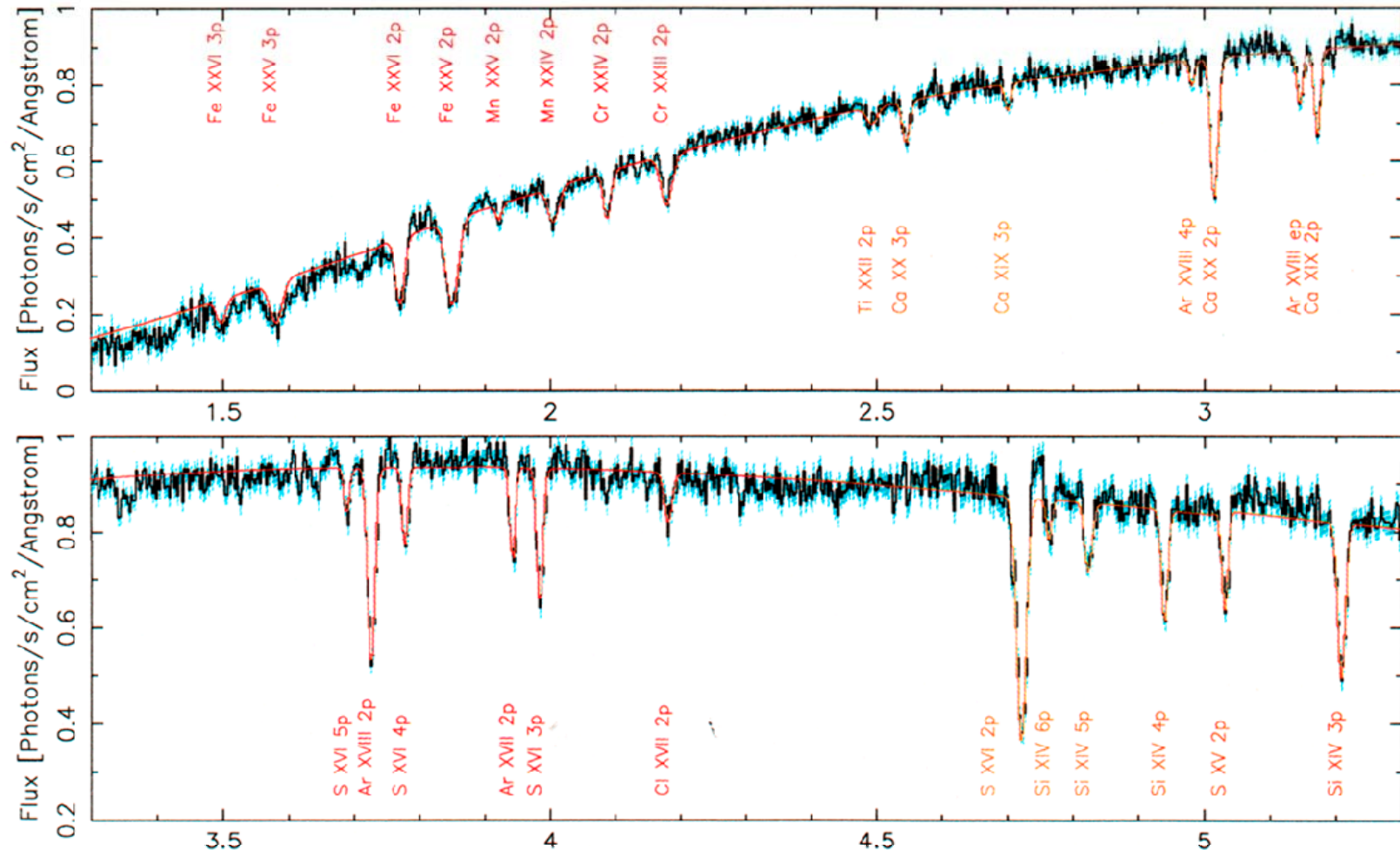
# Absorption Spectrum of GRO J1655-40 (1)

"The magnetic nature of disk accretion onto black holes"  
Miller et al. 2006 Nature 441, 953. (Fig. 1)



Absorption lines at low energy end of redshifted Fe line profile

## Absorption spectra of GRO J1655-60 at short wavelength (2)



This figure was not included in Miller et al, 2006 Nature 441, 953

# 1. Replace the iridium coatings of some SXT mirror shells with multilayers.

The results of ray tracing simulations indicated that while it is possible to extend the bandwidth of the SXT with multilayer coatings the gain was comparatively modest.

The efficiency of the cryogenic detector above 15 keV would have to be increased beyond its current baseline to achieve any benefit.

2. Reposition some SXT mirrors to smaller radii to reduce the mean graze angle with or without replacing the Iridium coatings with multilayers.

This would require a redesign of the SXT. The preliminary results of limited simulation studies indicate that the bandwidth can be extended by these means but it would be accompanied by a loss of area at lower energies. Also, the efficiency of the detector would have to be increased.

This study could be pursued in greater depth and more definitively if it is deemed desirable to do so.

3. Increase the size and mass of the SXT by adding more, smaller radii, mirrors within the vacant space between the innermost mirror and the optic axis

The new mirrors could be coated with multilayers for additional gain and there is obviously no loss of area at lower energies. The number of mirror shells is currently 230 per telescope. An additional 80 or more could be inserted.

**This approach increases the time required and difficulty of fabricating the SXT. The angular resolution may suffer as a result.**

Poorer Angular resolution will also affect dispersive spectroscopy

4. Insert a separate, complete telescope, i.e. an HXT, in the hole between the optic axis and the smallest shell of the SXT.

The second telescope could be fabricated by either the same or different means as the SXT.

**The point response of the second telescope will be superimposed upon that of the SXT and is not likely to be as good as the SXT's. The angular resolution of the system suffers.**

A solution is filtering the aperture of the second telescope to eliminate X-rays below  $\sim 15$  keV. A filter that attenuates 15 keV X-rays will reduce the efficiency of the second telescope up to 20 keV resulting in a reduction of the benefit.

# Problems common to Methods 1 to 4

## They violate the three principles

These hard X-ray additions are coaxial with or are part of the SXT. They increase the difficulty of developing, testing, and calibrating the SXT.

Their implementation may result in less angular resolution.

They require the use of detectors that are efficient 15 to  $\sim 40$  keV. Those detectors are not likely to have as good energy resolutions below 7 keV (where most of the lines exist) than detectors that free from this constraint.

# External HXT

An external HXT is the solution that does not violate any of the three principles.

The detector can be a CZT array, which is  $\sim 100\%$  efficient at 40 keV and below.

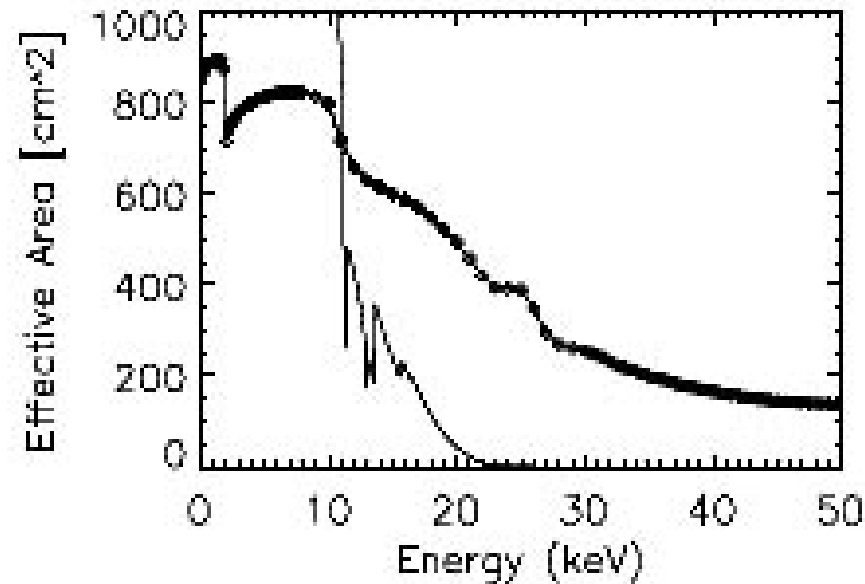
## 5. Separately Packaged HXT Outside of the SXT



HXT prototype with  
two mirror shells  
Tested at Panter  
facility

Our conclusion is that the best method of broadening the bandwidth is with separate HXT telescopes and dedicated CZT detectors. The detector has high efficiency. The design, fabrication and resolution of the SXT is not all subject to any influence of the HXT.

# Nominal Theoretical Effective Area, 2 HXT Modules



Effective area (broad curve) of the proposed 2-telescope HXT as a function of energy. The HXT detector efficiency is assumed to be high (e.g. CZT). The narrow curve is the SXT + detector area for the 4-telescope configuration.

# Effective area options

The effective area curve shown in the previous slide is based upon a specific multilayer prescription.

The effective area curve can be modified within limits by varying the prescription. For example we could maximize

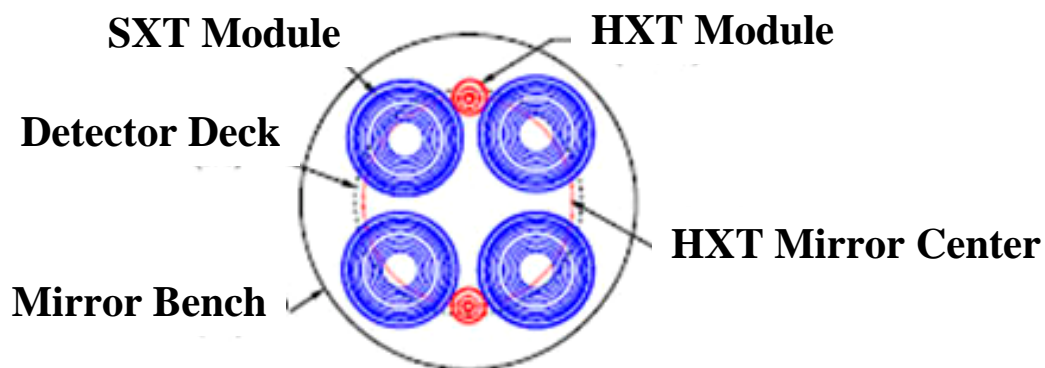
$$\int_{E1}^{E2} E^N Area(E) d(E)$$

For any values of  $E1$ ,  $E2$  and  $N$  according to the recommendations of the FST or other science driven considerations.

# Location of the HXT

We propose adding two HXT modules that are placed outside of the boundaries of the SXT. There is sufficient space up front for the optics and at the focal plane for the detectors.

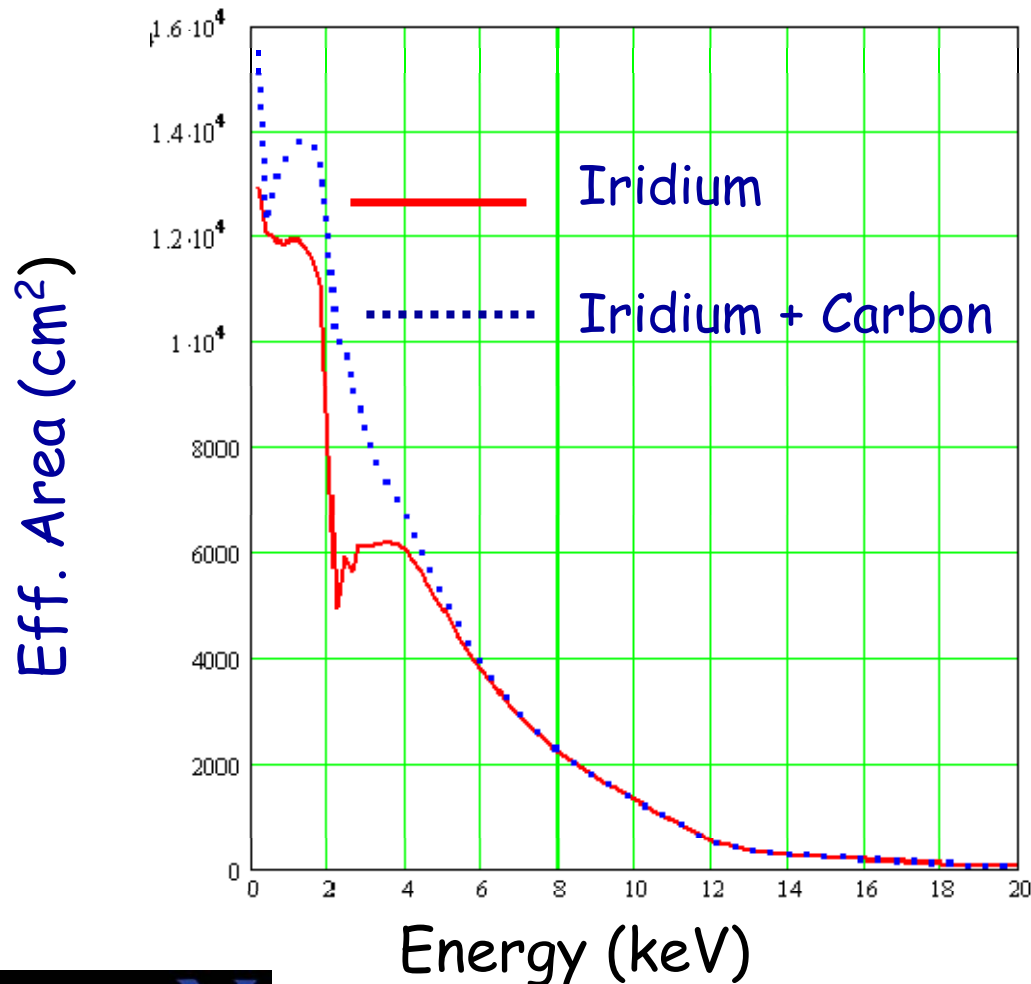
## HXT GEOMETRY



Our design is limited to 2 modules by the mass allowance. With a larger mass allowance we will obtain more area, either by adding more mirror shells or by adding up to two more HXT modules.

# Appendix of White Paper

## Benefit to SXT of 10 nm carbon overcoat upon iridium



# Appendix of White Paper

10 nm carbon overcoat may be acquired in storage

